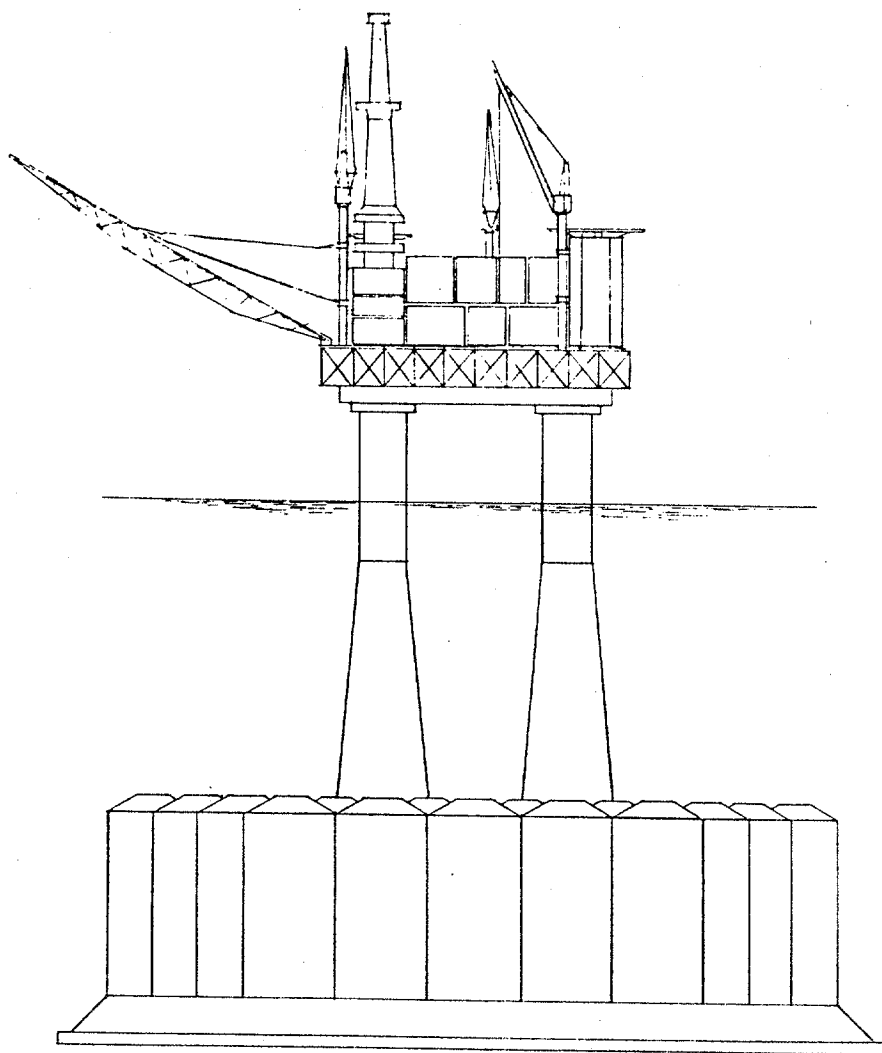
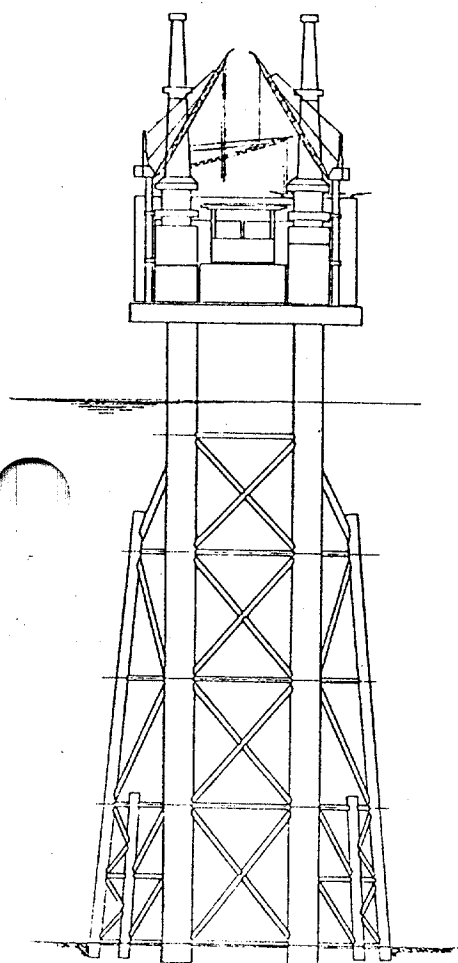


PROPRIETARY INFORMATION
UNTIL MAY 1, 1987

SOUTHERN BERING SEA PRODUCTION SYSTEMS STUDY



P M B SYSTEMS ENGINEERING INC.
BECHTEL PETROLEUM, INC.
BEN C. GERWICK, INC.
HARDING - LAWSON ASSOCIATES
VAUDREY and ASSOCIATES

EXECUTIVE SUMMARY

SOUTHERN BERING SEA PRODUCTION SYSTEMS STUDY

FINAL REPORT

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EXECUTIVE SUMMARY

A. INTRODUCTION

Future lease sales are scheduled to be held by the U. S. Department of Interior in the following regions of the Southern Bering Sea:

- St. George Basin
 - OCS 70 - February 1983
 - OCS 89 - December 1984
- Navarin Basin
 - OCS 83 - March 1984
 - OCS 107 - March 1986
- North Aleutian Shelf
 - OCS 75 - April 1983*
 - OCS 92 - April 1985

* Possible postponement

This project provides initial engineering and economic data related to permanent offshore drilling and production structures, topside requirements, crude oil pipelines, and terminals. Specifically, the following components were pursued through a preliminary engineering phase and cost estimates and schedules were prepared.

- Steel Pile Supported Platforms
- Concrete Gravity Platforms
- Topsides for 100,000 and 300,000 BPD

- Pipelines
- A Shore Terminal on the Alaska Peninsula
- Offshore Storage and Loading Structures

It is intended that these basic "building blocks" can be assembled by the sponsoring companies into reservoir development strategies which are consistent with their specific operating requirements and estimates of reserves. Design basis environmental conditions are presented and sensitivities to changes in environmental and operating requirements are discussed.

B. ORGANIZATION OF PROJECT

This project was sponsored jointly by the following companies:

AMOCO Production Company
Anadarko Production Company
Champlain Petroleum Company
Cities Service Oil Company
CONOCO Incorporated
Getty Oil Company
Gulf Research and Development Company
Marathon Oil Company
Mobil Exploration and Producing Services Incorporated
Occidental Exploration and Production Company
Pennzoil Company
Phillips Petroleum Companies
SOHIO Petroleum Company
Standard Oil Company of California
Superior Oil Company
Texaco Incorporated
Texasgulf Inc.

The project team consisted of the following organizations with PMB acting as prime contractor.

PMB Systems Engineering Inc.
Bechtel Petroleum Incorporated
Harding-Lawson Associates
Ben C. Gerwick
Vaudrey and Associates

C. DESCRIPTION OF LEASE SALE AREAS

The approximate locations of the St. George, North Aleutian Shelf and Navarin sedimentary basins are shown in Figure 1. These basins are near the southern limit of annual sea ice coverage. As a result, open water prevails in these areas for approximately eight months out of the year, with mid-June to mid-October nearly ice free.

In general, the sea ice environment for the St. George basin and the North Aleutian Shelf basin is less severe than for the Navarin basin. Primary sea ice features in these two basins may include sheet ice, broken ice and first year pressure ridges, not necessarily occurring every year. Scattered drift ice is also characteristic of the south-east St. George and south-west North Aleutian Shelf areas. In contrast, the Navarin basin has sea ice every year, with multiple rafting of sheet ice producing a total thickness of up to 10 feet. Significant ice loads may also occur in the northern Navarin area from single year unconsolidated pressure ridges.

Study of the local soil conditions in the south Bering Sea indicates that the surficial soils in the Navarin basin consist primarily of silts and fine sands with little clay. In the North Aleutian basin, the surficial deposits are considerably more sandy with the finer sands generally overlaying the coarser sands. In the St. George basin, the surficial deposits range from sands to silts to soft clays, where the fine grained soils are located along the center of the graben that forms the basin.

The seismic activity common to these three sedimentary basins is significantly less severe than that just south of the Aleutian Island chain.

St. George basin is considerably more active than the Navarin and North Aleutian basins; however, events at North Aleutian have the potential for being more intense. Furthermore, the seismic activity in the St. George basin increases going from north to south.

The meteorologic-oceanographic environment of the Bering Sea is similar to that of the North Sea. Broad, low-pressure storm systems move in a generally easterly direction across the Aleutian Islands. Open water fetches of 2000 and 1000 miles in east-west and north-south directions, respectively, characterize this sea. Ice coverage during the winter storm months may decrease the north-south fetch to 500 miles. Maximum extreme and operational sea states are expected to be similar to the North Sea. Annual and 100-year expected maximum wave heights are in the range of 60 to 90 feet, respectively.

D. DRILLING AND PRODUCTION STRUCTURES

Alternatives Evaluated

Prior to the initiation of preliminary designs for drilling and production platforms, several platform configurations were qualitatively evaluated.

Concepts evaluated included the following:

- Steel Pile Supported Structures
 - Self Floating Tower Type with Cluster Piles
 - Eight Leg Template with Skirt Piles
 - Four plus Four Template with Skirt Piles
 - Eight Leg Template with Caisson
 - Steel Monotower
- Concrete Gravity Structures
 - Four Leg Condeep Type
 - Condeep Monotower
 - Twin Tower
 - Tripod with Monotower
 - Chevron Monotower
- Floating Production Platform
 - Semi-Submersible

From this evaluation, the four plus four steel template with skirt piles and the four leg concrete gravity structure were selected as the most suitable concepts. See Figure 2.

Both of these structures have a clean water plane area with four main legs on spacing of 100 feet or more and no minor bracing. Wells and

risers are contained within the structure legs and there is no bracing in the area which could be affected by sea ice. They are also well suited to carry the large payloads anticipated for the Southern Bering Sea platforms.

Steel Pile Supported Platforms

The "four plus four" template is an eight-leg jacket with skirt piles. The two end bays terminate beneath the ice zone. This provides four large legs (two of which contain the wells) penetrating the water surface on a spacing of 100' x 140'. The legs in the ice zone are double wall with a concrete annulus to distribute local ice forces. The front face of the jacket is vertical, and the other three faces are battered at 1 to 12.

A summary of platform weight is given below along with the controlling load case for the base case conditions.

	<u>St. George</u>	<u>Navarin</u>	<u>No. Aleutian</u>
W.D.	450'	450'	300'
Payload	91800 k	91800 k	91800 k
Jacket	20380 T	20980 T	16,480 T
Piling	9030 T	11270 T	4350 T
Base Shear/ Controlling Case	1.3x10 ⁴ k Oceanographic	2.0x10 ⁴ k* Ice	1.2x10 ⁴ k* Ice
Overturning/ Controlling	4.5x10 ⁶ ft-k Oceanographic	9.0x10 ⁶ ft-k* Ice	3.8x10 ⁶ ft-k* Ice

*On diagonal attack

Construction requirements will include a large (600') launch barge and a 1600/2000 T semisubmersible derrick barge, both assumed to be mobilized

from the North Sea. High pile capacities may require hammers with capacities in excess of 1 million ft-lbs. The marine phase of construction can be completed in one season; assuming no unusual pile driving problems or abnormal summer weather conditions.

The steel "four plus four" platforms were found to be feasible for all lease sale areas, water depths, soil conditions and ranges of environmental conditions.

Concrete Gravity Structures

The concrete gravity structure is composed of a cellular base with a flared mat, steel skirts, and four main shafts on 130' x 150' spacing which support the deck. Two of the legs contain the wells. This structure is very similar to Statfjord B or C.

The bases of these structures have been designed to contain from 1 to 3 million barrels of storage.

A summary of structure concrete volumes is given below along with the controlling load case for the base case conditions.

	<u>St. George</u>	<u>Navarin</u>	<u>No. Aleutian</u>
W.D.	450'	450'	300'
Payload	91800 k	91800 k	91800 k
Storage	1 million barrels	1 million barrels	1 million barrels
Concrete Volume	227,000 cu. yd.	227,000 cu. yd.	138,000 cu. yd.
Base Shear/ Controlling Case	1.0×10^5 k Seismic	9.2×10^4 k Wave	1.5×10^5 k Seismic
Overturning/ Controlling	9.7×10^6 ft-k Seismic	12.6×10^6 ft-k Ice	11.9×10^6 ft-k Seismic

Fabrication requirements include a shallow graving dock and a deep water protected site to mate the deck with the gravity base. Such sites exist in Puget Sound and Japan, and an acceptable degree of skilled labor is available in each location. After mating the gravity base structure (GBS) and deck, several large tugs will tow the platform to location where it will be ballasted down, skirts penetrated and the underbase grouted.

The four leg concrete gravity structure was found to be feasible for all lease sale areas, water depths, and ranges of environmental conditions for the majority of soil conditions anticipated. Certain combinations of deep water or high environmental loading, or large storage requirements coupled with base case or lower bound soils were identified as potential limitations; however, mitigation measures are discussed. Other configurations, such as the tripod or quadripod, appear more adaptable to the conditions of very soft soils, deep waters, and strong seismicity.

Topside Requirements

A modular topside was configured for oil production cases of 100,000 BPD and 300,000 BPD. The modules for the steel structure would be placed offshore. The modules for the gravity structure would be placed on a support frame in a shipyard and this integrated deck subsequently mated to the GBS at a deep water near shore location.

The payload for 100,000 and 300,000 BPD was 63,100 k and 91,800 k, respectively (including topside structure steel). The deck plan area is about 160 ft. x 220 ft. and provides about 133,000 sq. ft. and 147,000 sq. ft. of total floor area for the two production cases.

Two drilling rigs are provided for both production cases, and a total of 30 and 48 well slots are assumed for 100,000 and 300,000 BPD, respectively, and are contained with the structure legs.

A total of 360 and 432 beds are provided for the two production cases. Proposed evacuation planning employs ice strengthened lifeboats and a safety ship (ice breaker during heavy ice, seasons) on standby at all times.

It may be generally concluded that production platform topsides in the Bering Sea are essentially the same as those in the North Sea with the following exceptions:

- More quarters for personnel are required because floatels are not thought to be practical in the potentially heavy sea ice.
- More storage capacity is needed for drilling consumables due to potential resupply delays.
- The maximum number of well slots per platform is limited to about 48 by the requirement that the conductors be protected from sea ice.
- Platform evacuation procedures and equipment require development to ensure personnel safety during an emergency in the presence of sea ice.
- Air and sea transportation is more expensive and more difficult due to ice conditions, fog and potentially long travel distances in addition to the consistently harsh climatic conditions.

E. TRANSPORTATION SYSTEMS

Pipeline

Submarine pipelines were conservatively sized to transport 100,000 BPD and 300,000 BPD from each basin to a shore terminal on the Alaska Peninsula. See Figure 3. Twenty-four inch diameter and thirty-six inch diameter were found to be suitable sizes for pipelines from all three basins; however, a booster station was required in the case of the Navarin Basin lines due to the long distances (approximately 600 naut. miles).

Total lengths of pipelines to the Left Hand Bay terminal are 65 naut. mi., 242 naut. mi., and 611 naut. mi. to the center of North Aleutian, St. George, and Navarin, respectively. This includes 16 miles of onshore line and 23 miles of submarine line across Herendeen Bay.

Construction requirements vary considerably for the three basins. One second generation lay barge working one season is adequate to construct either the 24" or 36" line to North Aleutian. Two second generation barges working two seasons are required to construct the 24" line to St. George, with a third barge used the first season only for the 36" line. Two third generation semi-submersible pipelay barges working two seasons are required for construction of the 24" line to Navarin with an additional second generation barge the first season only for the 36" line. Due to the very limited availability of the semi-submersible pipelay barges (3 total), it is assumed that two new vessels would be constructed for this project.

It is anticipated that acceptable pipeline routes can be established from all three lease sale areas to a shore base on the Alaska Peninsula. No unusual obstacles or engineering constraints are anticipated which are beyond the state of practice for other severe weather areas such as the North Sea.

Shore Terminal

After a review of alternative shore terminal locations on the rim of the Bering Sea and on the southern shoreline of the Alaska Peninsula, three sites (all on the southern shore of the Alaska Peninsula) were selected as possible candidates. Of these three, the one at Lefthand Bay (an arm of Balboa Bay) is preferred due to a combination of good access to open water, deep water close to shore, complete protection from sea waves, no sea ice, and a proximity to the preferred shore and construction base site on Herendeen Bay. Herendeen Bay lies directly across the Alaska Peninsula on the northern shoreline.

The shore terminal was configured for 100,000 BPD or 300,000 BPD throughput with expansion potential to 1,000,000 BPD. Components of the terminal include tankage for over 10 days of production, LPG and diesel facilities, tanker berth(s) stabilization and fractionation trains, power generation and quarters.

Offshore Storage and Loading

An offshore concrete gravity storage and loading structure was identified as an alternative to pipeline transportation of crude oil. See Figure 4.

This would be a separate structure, but located nearby the drilling and production platform.

Storage volumes from one to three million barrels of oil were investigated.

Tanker loading would be through a single point mooring mounted on a rigid column which would be a continuation of the central cell in the gravity base.

F. COST AND SCHEDULE

The total platform cost summaries for the three basins are shown in the attached Tables 1, 2 and 3. In addition, the total costs are presented graphically for platform costs versus water depth for 100,000 and 300,000 BPD for each basin in Figures 5, 6 and 7.

Pipeline, shore terminal and offshore loading structure costs are summarized in Table 4.

Schedules are shown in Figures 8, 9 and 10 for steel platforms, concrete platforms and transportation systems.

General conclusions which can be drawn include:

- Cost
 - Steel platforms tend to be less costly than concrete gravity platforms for all locations.
 - The primary role of the concrete gravity platforms may be as a central drilling/production/storage facility with companion steel structures as drilling or drilling/production platforms. For the full economy of the gravity platforms to be realized, they should be used in conjunction with an offloading structure such as the guyline supported SALM/CALM discussed in Section 3. More work is needed to assure feasibility of such an all weather SPM.
 - Offshore storage and loading structures are lower in capital costs for all basins as compared to pipeline plus shore terminal costs. This does not consider downtime of the offshore terminal or differential tanker costs.

- Schedules

- Steel and concrete platforms are relatively comparable in time required to initiation of drilling 67 months vs. 70 months.
- Transportation systems are not likely to be the critical path.

G. RECOMMENDATIONS FOR FUTURE WORK

The following are areas which warrant work prior to initiation of site specific designs in order to confirm feasibility and cost of the proposed development systems.

- Criteria
 - Ice interaction with multi-leg structures and effects of leg spacing on total loads.
 - Design criteria for multi-hazard environment.
 - Oceanographic characterization for wave-ice interaction and fatigue evaluations.
 - Seismic attenuation and amplification study for Southern Basins. Determination of seismic parameters such as spectral velocity, displacements, and duration.
- Topside
 - Evaluation of minimum topsides, especially for areas in the most southern (least remote) basins.
 - Evacuation planning.
 - Gas production case.
- Steel Structure
 - Fatigue evaluation and methods of stiffening deeper water structures to reduce natural periods.
 - Details of large leg stiffening and initial evaluation of punching shears on legs.
 - Reproportioning of foundations to reduce pile axial loads and initial pile drivability evaluation.

- Pipelines
 - Gas production case.
- Shore Terminal
 - Gas production case.
- Offshore Storage and Loading
 - Evaluation of mooring and product transfer hardware in cold environment.
 - Tanker impact resistance of shaft.
 - Demurrage and downtime study.
 - Feasibility of guyline supported SALM/CALM for continuous operations.
- Floating Production Systems
 - Downtime evaluation of candidate semisubmersible systems.

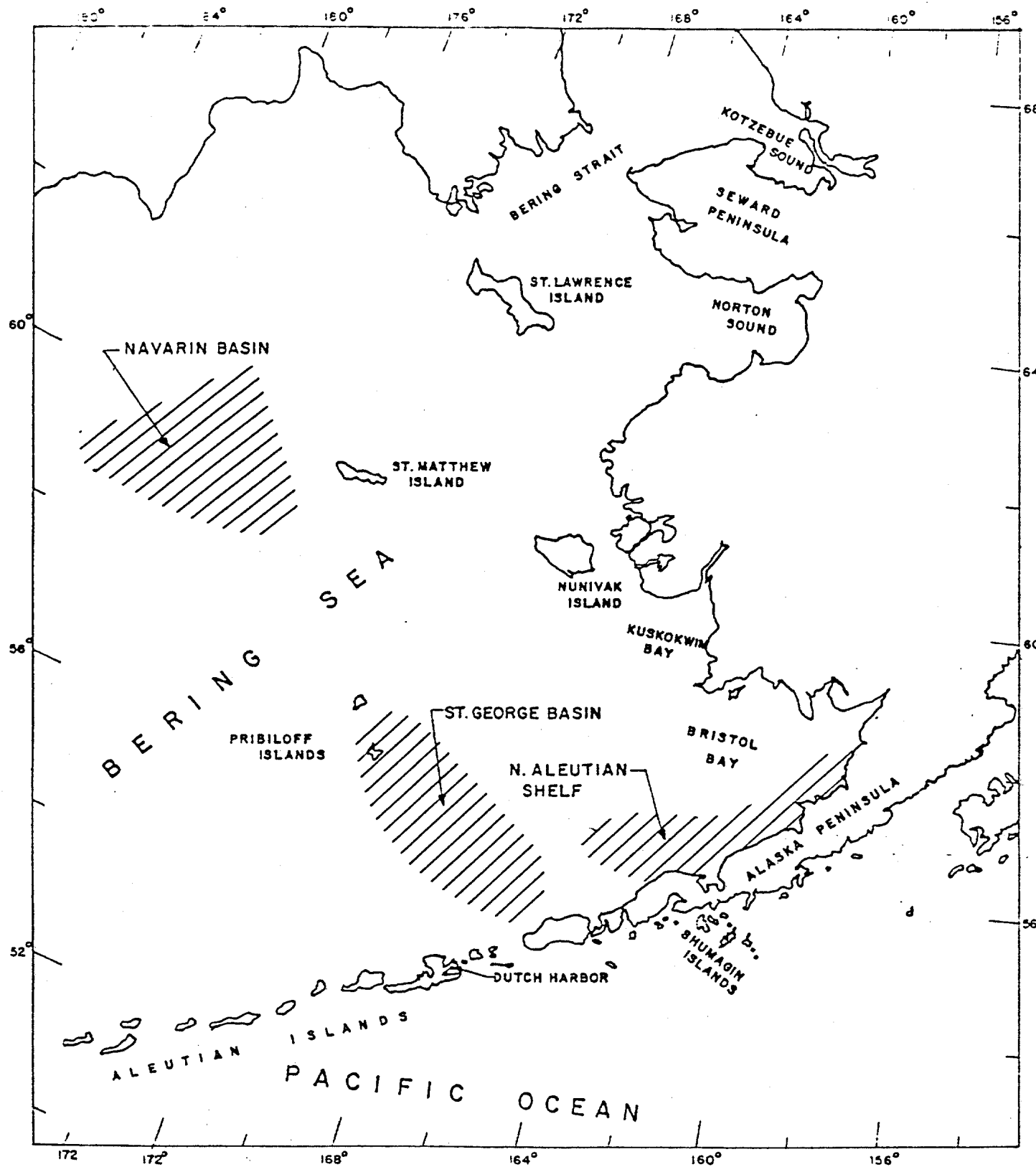
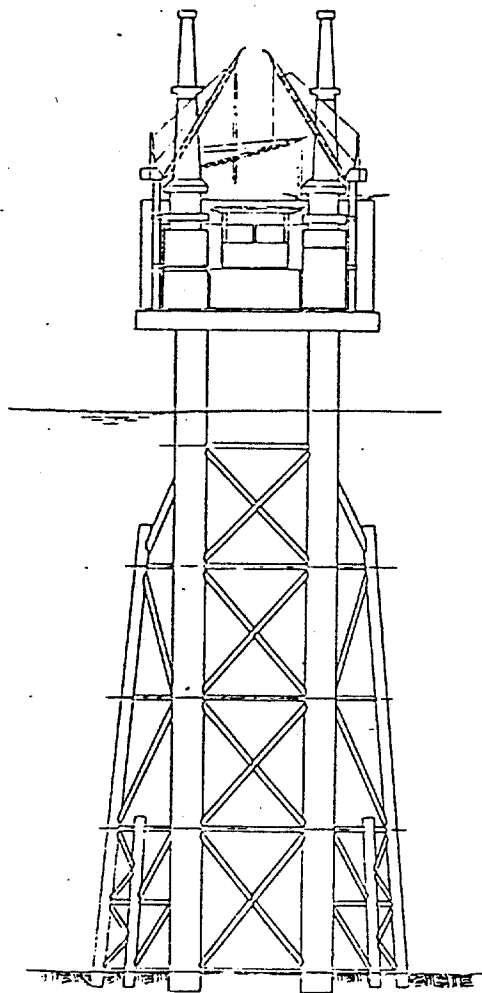
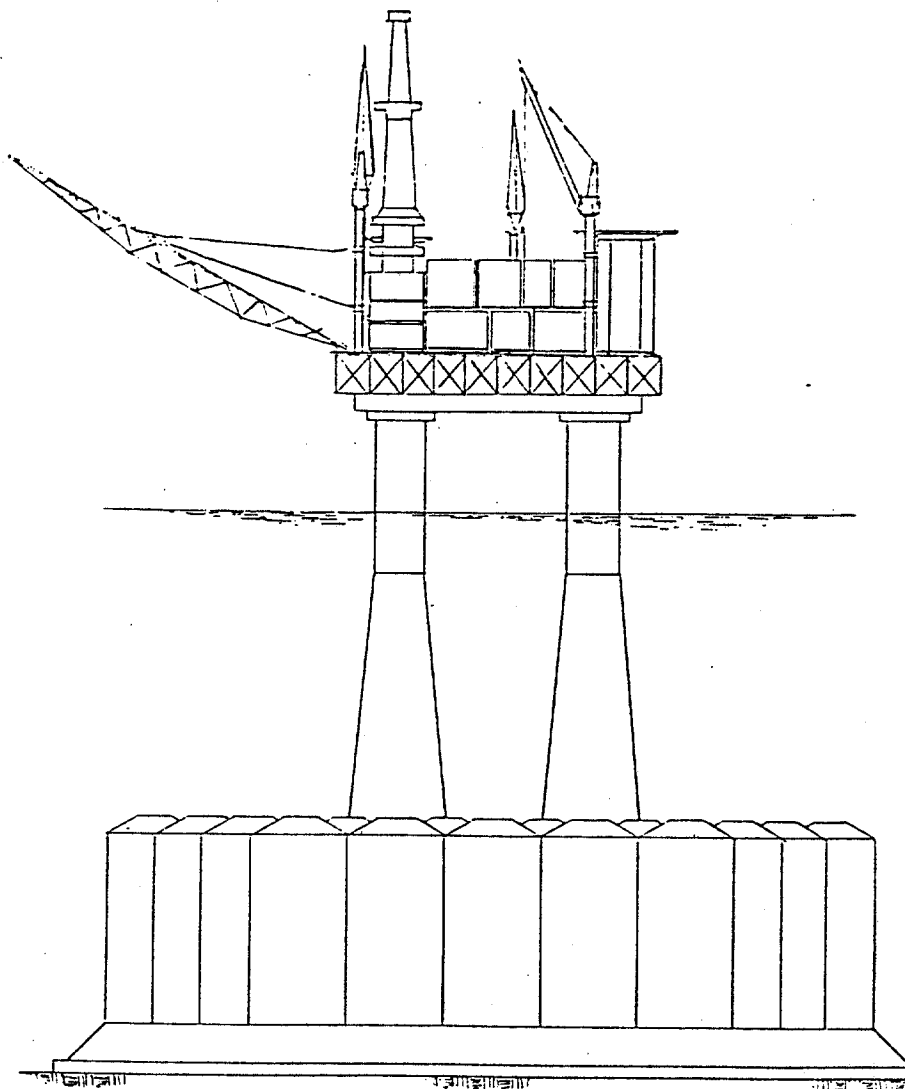


Figure 1 - SOUTHERN BERING SEA

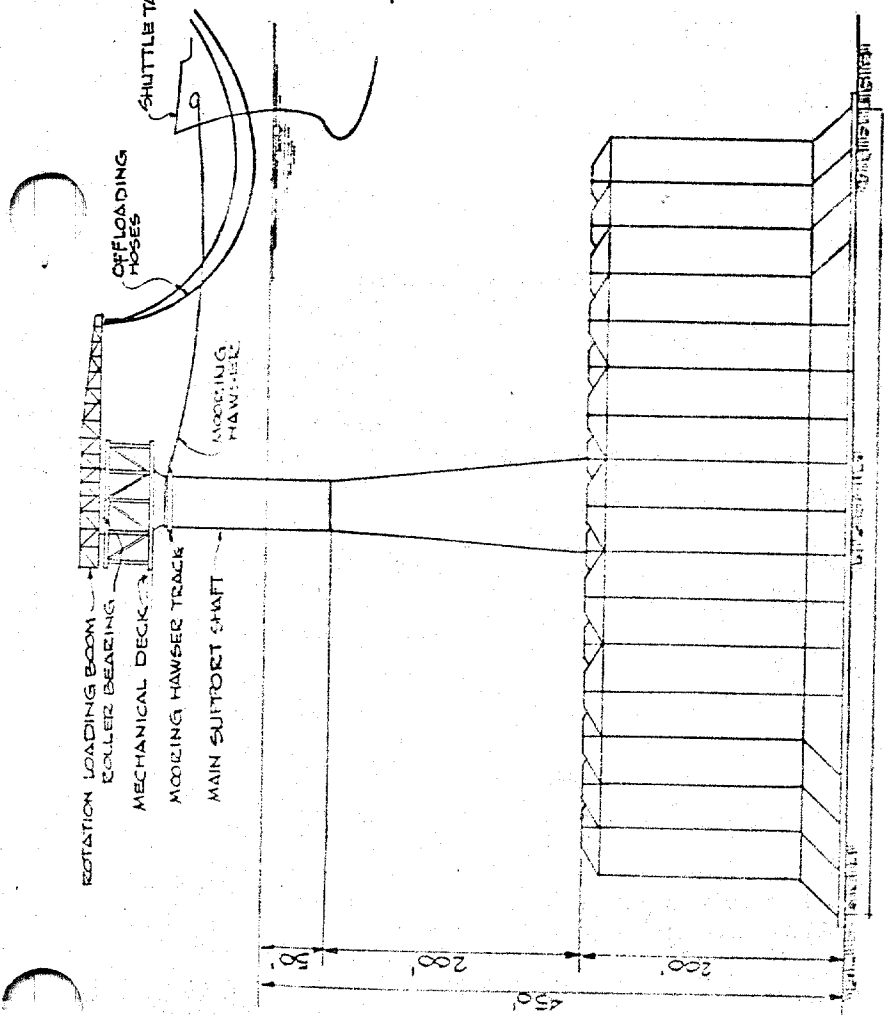


FOUR PLUS FOUR TEMPLATE

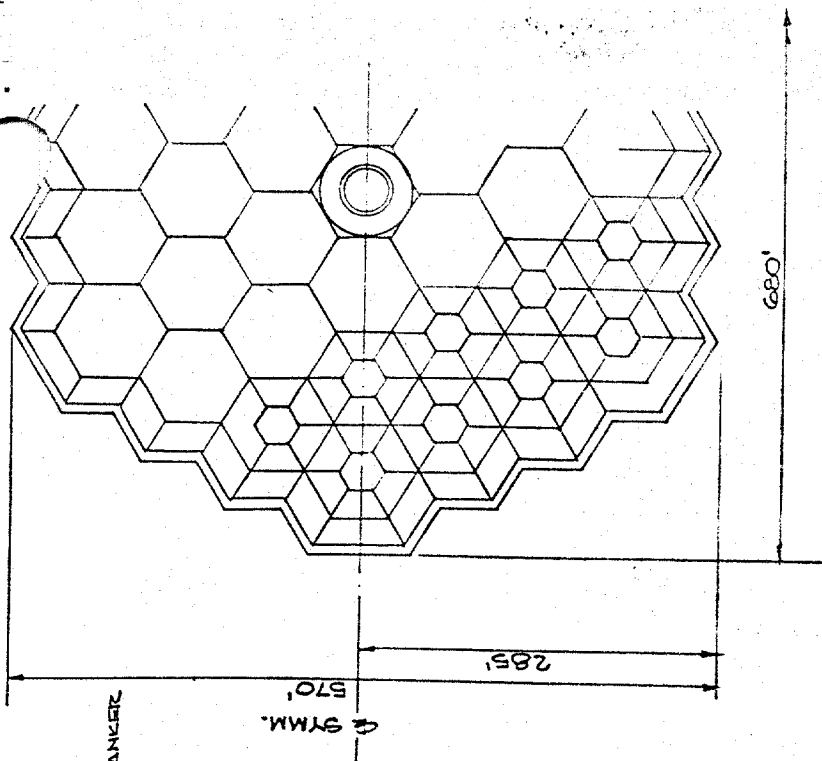


CONCRETE GRAVITY STRUCTURE

FIGURE 2



ELEVATION



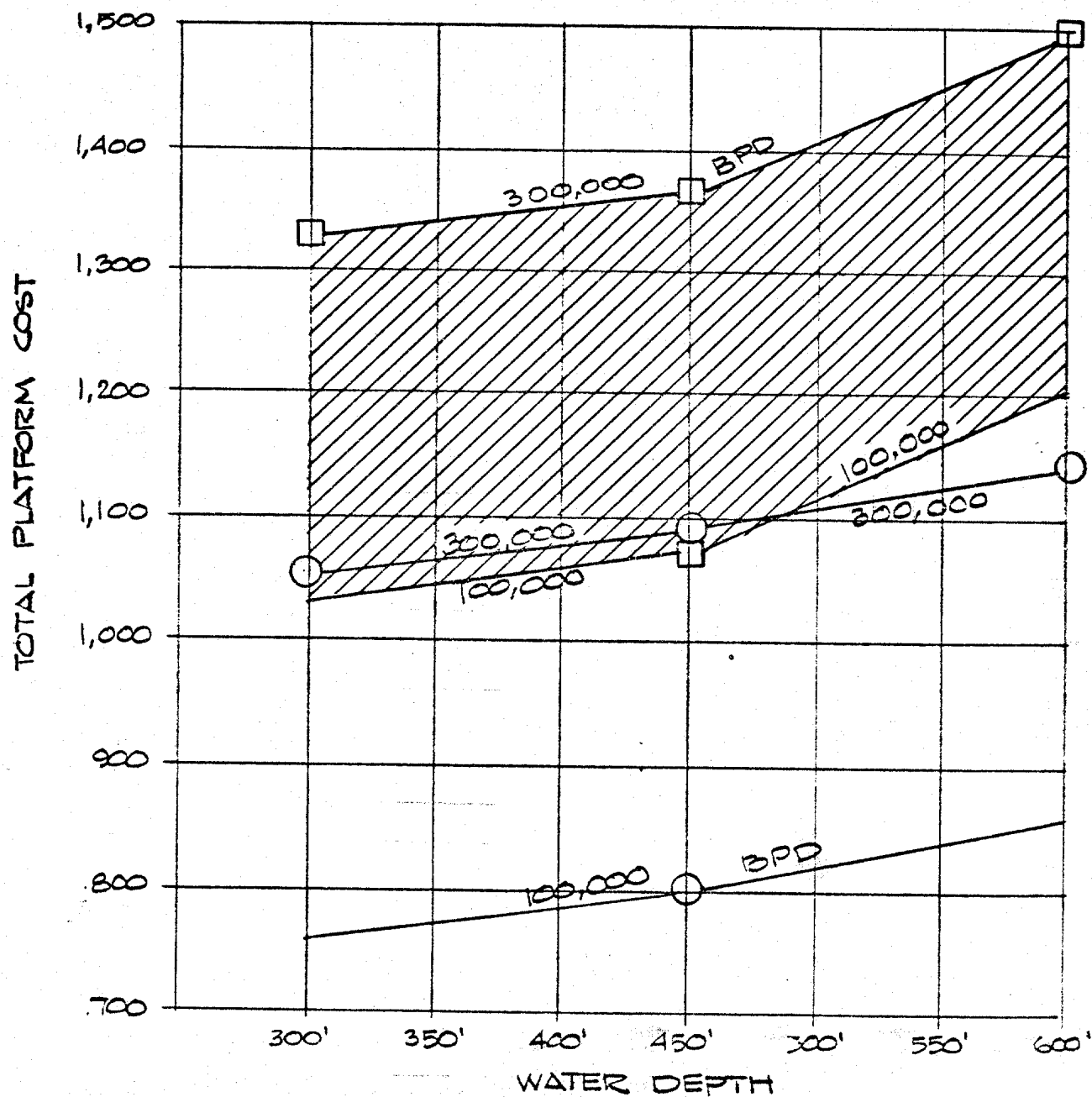
PLAN

CONCRETE STORAGE/LOADING STRUCTURE
 WATER DEPTH 450 FT.
 STORAGE CAPACITY 3,000,000 BBL

FIGURE 4

SOUTHERN BERING SEA PRODUCTION SYSTEMS STUDY

ST. GEORGE BASIN
PLATFORM COST VS. WATER DEPTH
100,000 BPD AND 300,000 BPD
(US \$ x 10⁶ 1982)



□ CONCRETE GRAVITY STRUCTURE
○ STEEL STRUCTURE

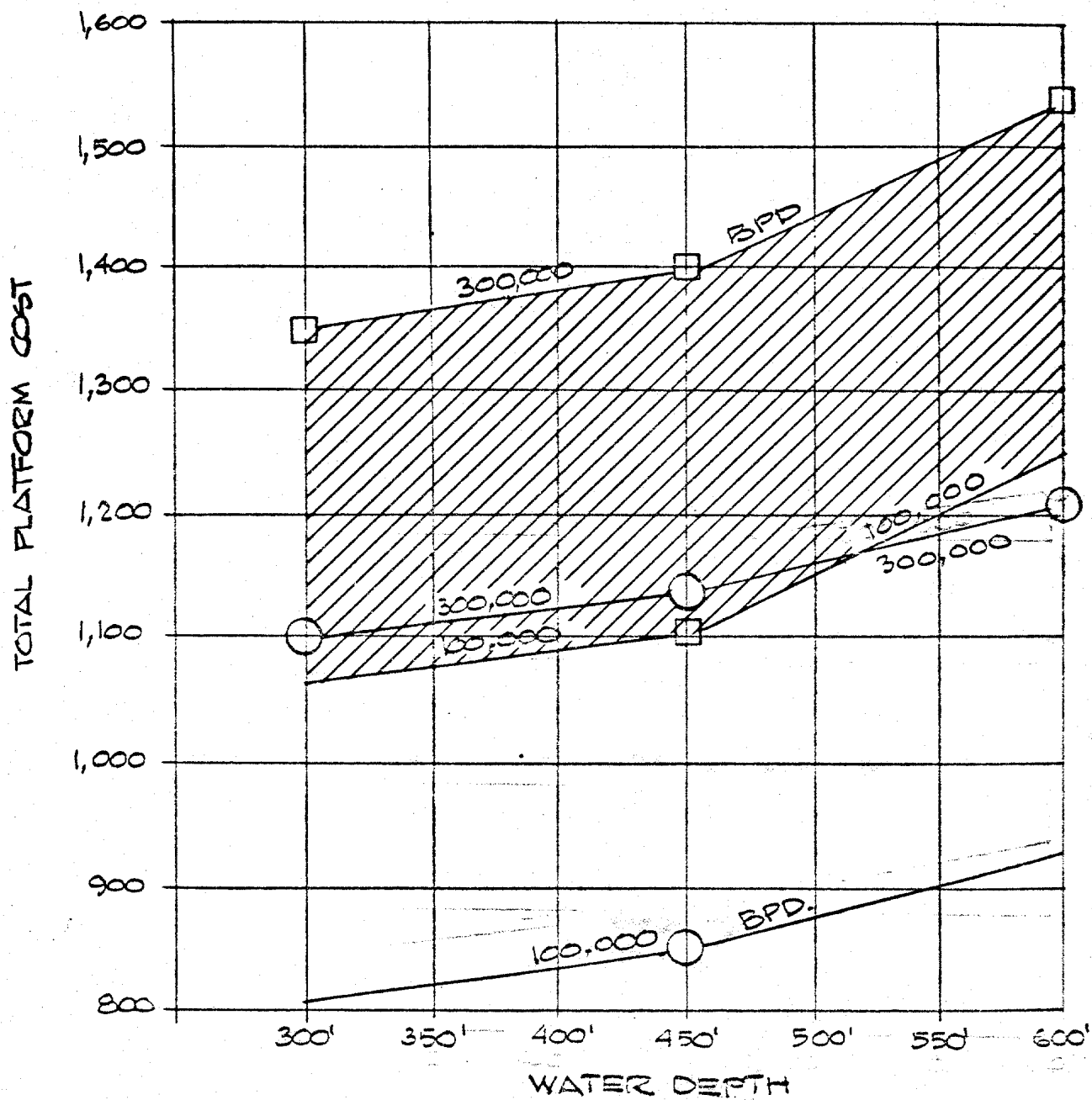


FIGURE 5

SOUTHERN BERING SEA

PRODUCTION SYSTEMS STUDY

NAVARIN BASIN
 PLATFORM COST VS. WATER DEPTH
 100,000 BPD AND 300,000 BPD
 (US \$ x 10⁶ 1982)

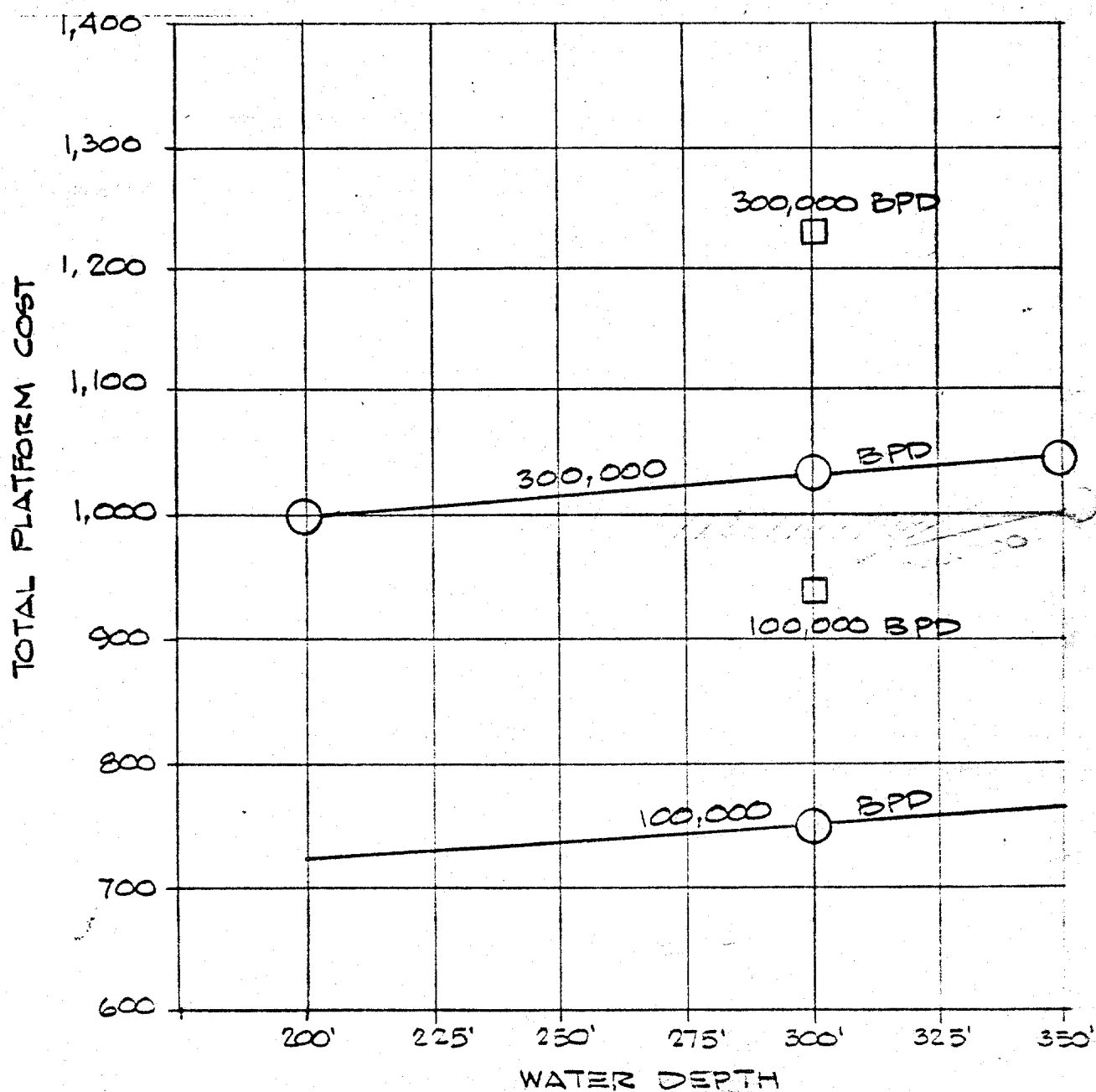


- CONCRETE GRAVITY STRUCTURE
- STEEL STRUCTURE

FIGURE 6

SOUTHERN BERING SEA PRODUCTION SYSTEMS STUDY

NORTH ALEUTHIAN BASIN
PLATFORM COST VS. WATER DEPTH
100,000 BPD VS. 300,000 BPD
(US \$ $\times 10^6$ 1982)



- CONCRETE GRAVITY STRUCTURE
- STEEL STRUCTURE

FIGURE 7

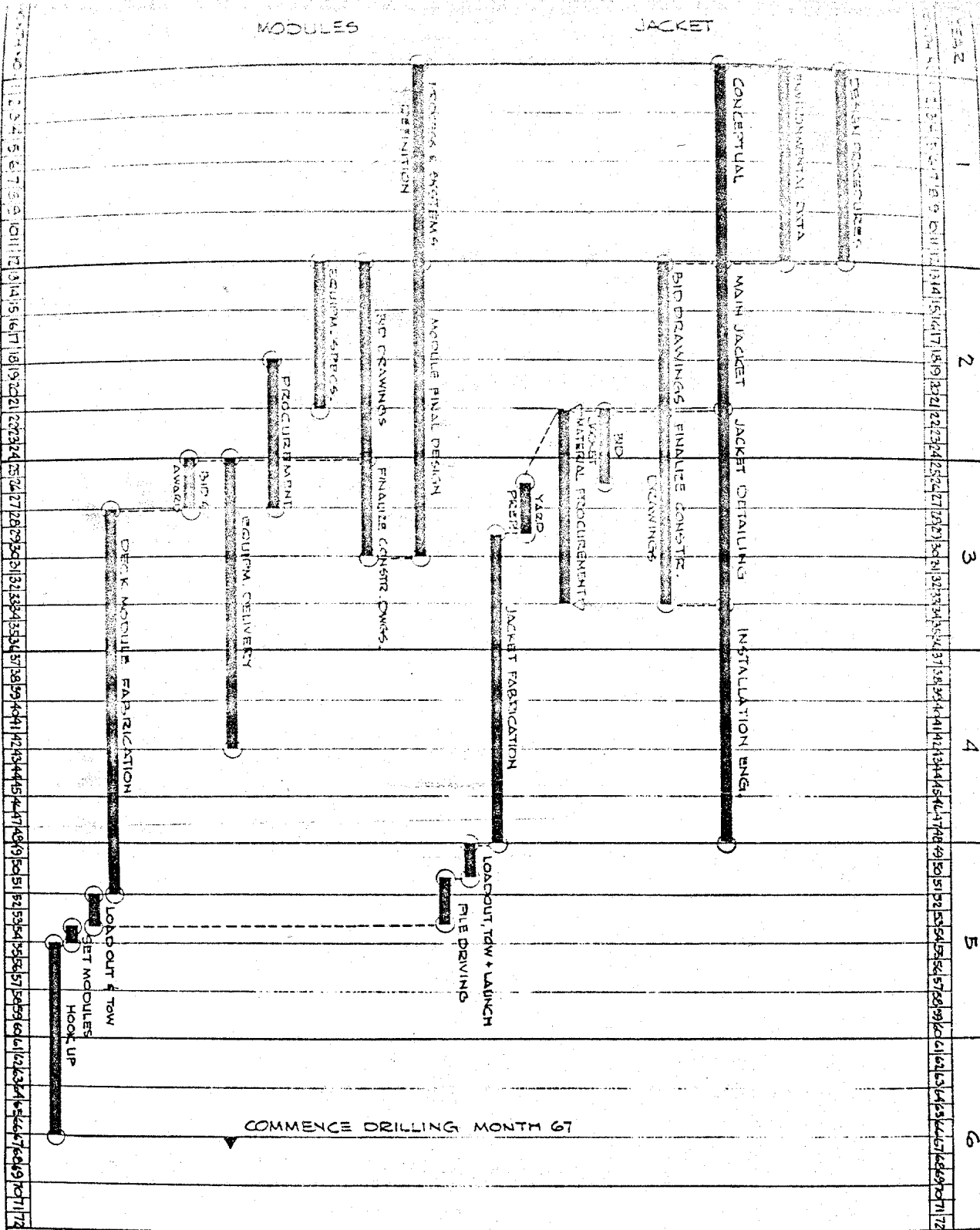


FIGURE 8
SOUTHERN BEIRING SEA
PRODUCTION SYSTEMS STUDY
MASTER SCHEDULE
STEEL PLATFORM

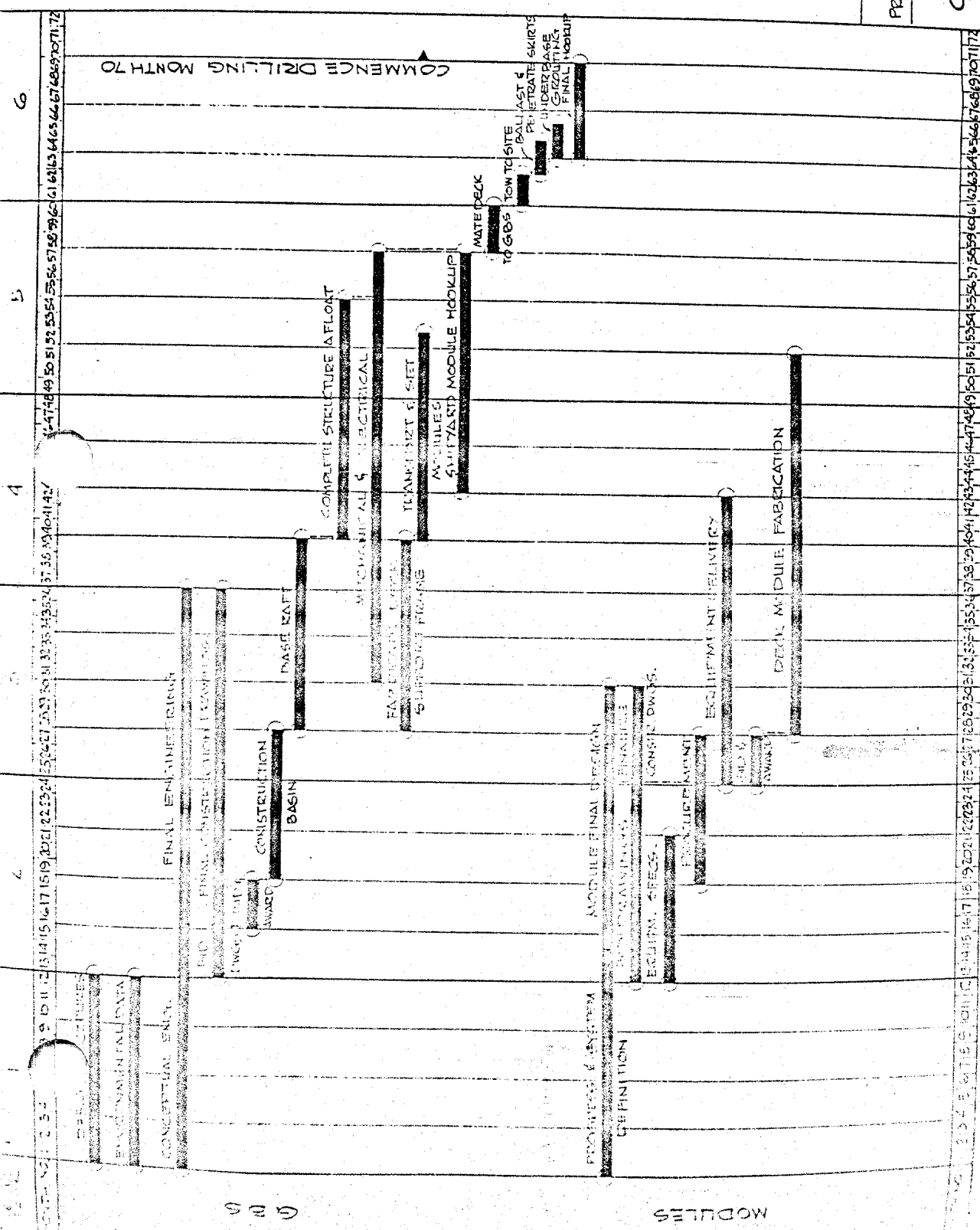


FIGURE 9

SOUTHERN BERLING SEA
PRODUCTION SYSTEMS STUDY

MASTER SCHEDULE
CONCRETE PLATFORM

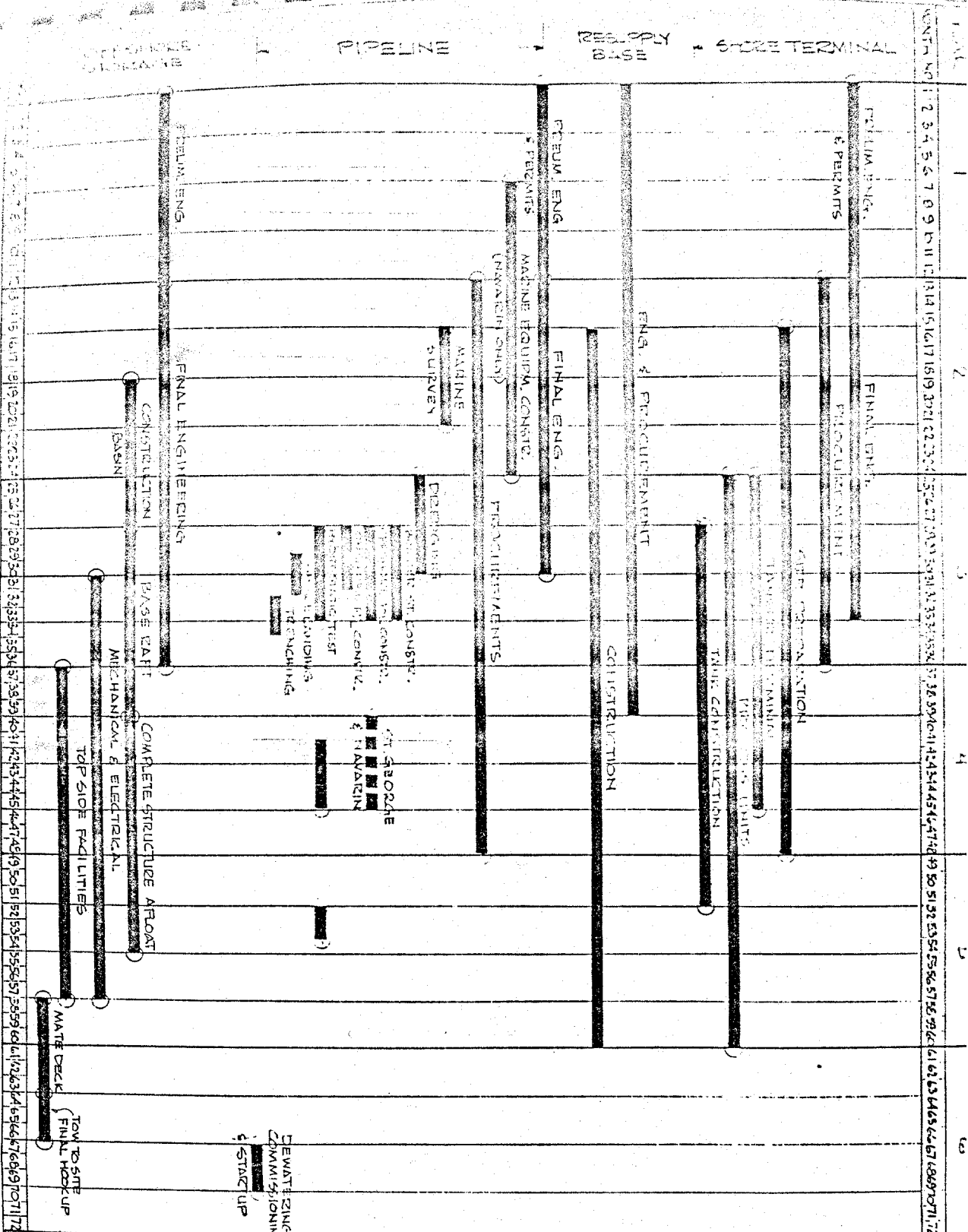


Figure 10

SOUTHERN BEARING SEA
PRODUCTION SYSTEMS STUDY
MASTER SCHEDULE
TRANSPORTATION SYSTEM

TABLE 1

SOUTHERN BERING SEA
 PRODUCTION SYSTEMS STUDY
 PLATFORM COST SUMMARY

ST. GEORGE BASIN
 (U.S. \$ x 10⁶)^{1,2}

	<u>100,000 BPD</u>	<u>300,000 BPD</u>		
	<u>450'</u>	<u>300'</u>	<u>450'</u>	<u>600'</u>
Steel Structure				
- Installed Structure	302	292	326	377
- Topside and Hookup	<u>505</u>	<u>764</u>	<u>764</u>	<u>764</u>
- Total	807	1056	1090	1141
Concrete Structure ³				
- Installed Structure	545	542	582	724
- Topside and Hookup	<u>539</u>	<u>788</u>	<u>788</u>	<u>788</u>
- Total	1084	1330	1370	1512

¹All costs include a 30 percent contingency

²June 1982 costs, no escalation

³Includes 1.2 million barrels of oil storage. Subtract \$100 x 10⁶ for no storage case

TABLE 3

SOUTHERN BERING SEA
PRODUCTION SYSTEMS STUDY
PLATFORM COST SUMMARY
NORTH ALEUTIAN BASIN
(U.S. \$ x 10⁶)^{1,2}

	<u>100,000 BPD</u>	<u>300,000 BPD</u>		
	<u>300'</u>	<u>300'</u>	<u>450'</u>	<u>600'</u>
Steel Structure				
- Installed Structure	266	244	282	296
- Topside and Hookup	<u>493</u>	<u>752</u>	<u>752</u>	<u>752</u>
- Total	759	996	1034	1048
Concrete Structure ³				
- Installed Structure	413	--- ⁴	449	--- ⁴
- Topside and Hookup	<u>533</u>	<u>782</u>	<u>782</u>	<u>782</u>
- Total	946	--- ⁴	1231	--- ⁴

¹All costs include a 30 percent contingency

²June 1982 costs, no escalation

³Includes 1.2 million barrels of oil storage. Subtract \$100 x 10⁶ for no storage case

⁴Case not developed.

TABLE 4

SOUTHERN BERING SEA PRODUCTION SYSTEMS STUDY

TRANSPORTATION SYSTEM COST SUMMARY

(U.S. \$ x 10⁶, 1982)

	ST. GEORGE			NAVARIN			NORTH ALEUTIAN		
	100,000 BPD	300,000 BPD	100,000 BPD	300,000 BPD	100,000 BPD	300,000 BPD	100,000 BPD	300,000 BPD	300,000 BPD
A. PIPELINE	1080 (24")	1480 (36")	2100 (24")	2800 (36")	440 (24")	520 (36")			
B. SHORE TERMINAL	560	780	560	780	560	780			
C. RESUPPLY BASE	320	320	320	320	320	320			
D. OFFSHORE STORAGE AND LOADING	563	721	563	720	456	562			